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THE EXPERIMENTAL MINE OF THE UNITED STATES BUREAU OF MINES

BY

G. S. RICE, H. P. GREENWALD, AND H. C. HOWARTH

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THE EXPERIMENTAL MINE OF THE UNITED STATES BUREAU OF MINES[1]

By G. S. Rice,[2] H. P. Greenwald,[3] and H. C. Howarth[4]

INTRODUCTION

The Experimental Mine of the United States Bureau of Mines is a unique coal mine that serves as a large-scale testing laboratory. It is used primarily for testing the explosibility of coal-dust and gases but is also the workshop for many other kinds of research work of which the chief object is to increase safety in mining.

The mine is situated in Allegheny County, Pa., about 13 miles southwest of Pittsburgh among the high hills of the west bank of the Monongahela River, at the northeastern edge of the gas-coal district of the Pittsburgh coal bed which extends south through the Connellsville coking-coal district into West Virginia. The Pittsburgh bed, of the Upper Carboniferous age, is one of the most extensive continuous coal beds in the United States, if not in the world. Throughout large areas it shows remarkable uniformity of thickness, levelness, and character of coal, which is a coking coal of high-grade bituminous rank. Its thickness in the northern part is 5 to 5½ feet and in the central and southern part is 7 to 9 feet.

The Experimental Mine tract, containing 77 acres of surface and 38 acres of coal about 5 feet thick, lies in the spur of a hill, and the coal outcrops around this spur. On the south and southwest the area is bounded by old workings of an adjacent mine from which the pillars have been extracted, but it is separated from these workings by a continuous barrier pillar.

Adjacent to the Experimental Mine openings is the Explosives Testing Station of the Bureau of Mines. The power plant of the mine also serves that station.

The mine was developed in 1910 from the outcrop of the coal bed primarily for coal-dust and coal-dust and firedamp testing. The problems studied may be grouped as follows:

Relative explosibility of coal-dusts of different kinds, their relative ignitability in air and manner of explosion propagation.
Coal-dust explosion limitation and prevention methods.
Firedamp diffusion and explosion processes.
Ventilation methods in mines and vehicular tunnels.
Fire extinguishment apparatus, and other agencies.
Testing of explosives as concerns practical effects.
Strength of mine stoppings of different construction to resist explosions.
Compressibility and bearing strength of coal in place horizontally as a buttress and vertically as a pillar.
Roof movements and testing of roof pressures.
Roof protection methods such as guniting.

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Other work at the mine includes instruction of miners and officials in mining hazards, also the training of men in the use of rescue apparatus and testing devices etc., and the demonstration of mining hazards, particularly explosion hazards. Such demonstrations have been observed by many thousand persons.

Details of the problems investigated or under investigation are given later.

CHARACTER OF EXPERIMENTAL MINE PASSAGES

The mine is opened into the outcrop on the south side of a narrow valley by two parallel main entries, called the main entry and main air course, which run southward and are 1,300 feet long. There is a short single side entry, with testing chambers at the head, turned off the main entry to the right (westward) about halfway to its face, and two pairs of side entries, termed "butt entries," turned left (eastward) off the parallel main air course. The entries of the inby pair are 528 feet long and can be extended no further because of shallow cover, as their faces approach the outcrop in the valley next to that from which the mine drifts enter. From the outby entry of this pair seven rooms have been turned.

The entries of the outby pair are newer (1929) and have been driven only about 200 feet from the main air course at the time of writing (May 1933). They are parallel with the axis of the spur and will be approximately 1,200 feet long before reaching as close to the outcrop as advisable in order to leave sufficient roof cover. Two narrow headings have been driven southward off the outby pair of butt entries, for carrying on compressibility-of-coal tests. These headings are so located that they can be widened into rooms if desired.

The mine arrangements, as will be noted in the accompanying plan, are similar to those of the conventional room-and-pillar layout of a small mine in the Pittsburgh district. The entries are 9 to 10 feet wide and 50 feet from center to center; the rooms are 20 feet wide and 44 feet center to center. Crosscuts have been made 100 to 200 feet apart but the crosscuts of the main entries have been sealed by strong reinforced concrete stoppings.

The roof and ribs of the standard explosion-testing zone have been gunited and the floor concreted. This is advisable on several accounts: It prevents dust abraded from the Pittsburgh bed from entering into the explosion tests; it aids complete cleaning, which is especially important when the dust under test is changed in character or when dust-density tests are made; and it protects the roof and ribs from weathering and from breaking down from effects of the explosions. The gunite is put on naturally irregular walls with the object of duplicating practical conditions found in mine passages, which irregularity is a factor in causing turbulence of the air in an explosion, and consequent more uniform mixing with air of the dust raised by the advance air waves that always precede an explosion.

CHARACTER OF ROOF AND OVERBURDEN

The immediate strata over the coal bed consist of "draw slate" or clayey shale normally 6 to 10 inches thick but thickening locally to more than 3 feet, above that an interbedded layer of mixed bony coal and shale about 2 feet thick, and over that bituminous shales weak in strength. The surface consists principally of clay, from the weathering of the shales, and a thin layer of soil. The maximum thickness of cover over the mine is 130 feet at a place about 775 feet from the mouth of the main entry.

Face and butt joint planes are strongly marked in the coal, as is characteristic through out the Pittsburgh bed. The direction of the main entries and the room is nearly at right angles to the "face joints."

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POSITION OF MINE WITH REFERENCE TO SURFACE TOPOGRAPHY AND OTHER MERITS OF LOCATION

As previously mentioned, the main entrances of the mine are drift openings in the south side of a narrow valley and in a line directly opposed by the steep north bank. When explosions are of violent character the side hill receives the force and flames of the explosion and deflects them upwards, thus preventing, except in the most violent explosions, the air wave effects which are likely to cause damage to dwellings in the vicinity. This is important, as there has been much destruction of windows in the vicinity of surface galleries in Europe where these galleries were in flat country as at Liévin, France, and Altofts, England. Even with this protection, very violent explosions issuing from the Experimental Mine have broken windows at points over a mile distant.

Other factors entered into the selection of the location of the mine in 1910. It was desired to obtain an area of coal bed which would be practically free from methane given off by the coal (which condition was fulfilled by the site chosen on account of unrestricted drainage of gas to outcrops) yet have gas available for testing. The latter condition was obtained by having natural-gas wells and a gas line in the vicinity from which gas is obtained for making tests. Another condition sought was to obtain a coal area where the mine would be virtually self-draining of water. At the location chosen there is a slight dip of the bed toward the entrances so that only a small amount of pumping from depressions is required. With the exception of the faces of the inner pair of left butt entries, the coal bed had been found naturally dry.

HISTORY

A series of great coal-mine explosion disasters occurred a quarter of a century ago which caused World-wide apprehension in the coal industry. These began with the Courrières disaster in France (1906) in which 1,100 men were killed; this was followed by a number of major explosion disasters in England and by many in the United States in 1907, culminating in a great explosion at the Monongah Mine in West Virginia in which 358 men were killed. These happenings naturally caused all coal-mining men much anxiety and led to the appropriation of funds for Federal investigations into the causes of coal-mine explosions and other mine accidents. The investigations were placed under the Technologic Branch of the U.S. Geological Survey, which had been carrying on fuel investigations, and the appropriation was made available July 1, 1908.

Mining engineers were engaged to study the effects of explosion disasters. These investigations were supplemented by chemical investigations of different coals and mine gases, conducted in a laboratory and testing station established on the old Arsenal grounds at Pittsburgh.

At that period the explosibility of firedamp or methane was well known, as was the inflammability of coal-dust, but most mining men considered that it was not possible for coal-dust to propagate flame from a source of ignition by itself, and that the presence of methane was always required. However, this belief was shaken by explosions occurring in so-called nongassy mines; at that period these occurred most frequently at the time of firing shots. Laboratory testing in small models and also testing in short surface galleries had been extensively tried in various countries but with very conflicting results because, we now know, the size and kind of coal-dust, the density of the dust cloud, the amount of inert matter present, the source of ignition, and the release of pressure through openings or joints were factors seldom controlled, neither was their significance understood.

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In 1907 the French established a testing gallery not far from the Courrières Mine in the north of France and in 1908 the British established a somewhat similar gallery near the Altofts colliery, England, which colliery in the past had experienced a disastrous explosion. At the beginning of the Federal investigations in this country, engineers were sent (1908) to study the testing then being carried on in France and England. As a result of their report a gallery 100 feet long by 6 feet 4 inches in diameter was installed at Pittsburgh, principally, however, for the testing of safer explosives for use in gassy and dusty coal mines.

In this gallery many demonstration tests showing the explosibility of coal-dust were carried on in the presence of mining men, but it became evident from the comments by these men that they were not convinced that a relatively short gallery could duplicate conditions in a coal mine. Following the establishment of the Bureau of Mines by act of Congress effective July 1, 1910, to take over the mining investigations and fuel testing of the U.S. Geological Survey, the late Dr. Joseph A. Holmes, then director of the Bureau of Mines, decided to obtain a mine for experimental purposes. He instructed the chief mining engineer, George S. Rice, to find a mine, preferably in the Pittsburgh coal bed, as mines in this bed had experienced a large number of explosion disasters.

After examination of a number of abandoned mines which were offered by their owners, none of which was deemed suitable, it was decided to open a new mine to obtain the desired arrangements.

Various tracts of coal were examined with the cooperation of Pittsburgh coal operators, and finally a suitable tract of Pittsburgh coal was selected and leased from the Pittsburgh Coal Co. The "Experimental Mine" was then started in the summer of 1910 by driving entries into the outcrop of the coal bed.

Some years later when the Government investment in the mine development, structures and equipment had become increasingly large, negotiations were begun for purchase of the coal tract and the surface lands needed for use in the mine testing work and the explosives-testing laboratories and equipment which had been moved from Pittsburgh to the site adjacent to the Experimental Mine. In 1924 this purchase was consumated.

DETAILED PROBLEMS STUDIED

The following problems have been studied. Some of them have been completed; others are continuing or may be taken up again when time or financial conditions permit:

Testing of Explosibility of Coal-dusts

The problem of coal-dust explosibility has developed so many ramifications during the years of study and testing devoted to it that its essentials are best grasped by recognizing certain subdivisions. The present summary of testing is divided into three parts:

(A) Tests having to do primarily with the ignition of coal-dust and the initiation of explosions;

(B) Propagation of explosions after initiation; and

(C) General physical and chemical phenomena of explosions.

The foregoing testing applies to different coal-dusts with various characteristics.

(A) Ignition of coal-dust:

1. Initial ignition of coal-dust by different sources:

(a) By explosives, either in blow-out or mud-capped shots. Tests have been made of the ignition of coal-dust by dynamite, which is sometimes used in mud-capped shots to break large rocks as in coal mines. These tests and demon-

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strations are conducted on the outside of the mine as well as in one of the portals, and demonstrate the hazard of this method as compared with the use of block holes.

(b) By the explosion of gas-air mixtures prepared by admitting gas behind a diaphragm erected to confine the mixture to a definite volume.

(c) By electric arcs.

Tests have been made to determine the minimum electrical arc which will ignite a pre-made cloud of coal-dust; this has special application both at the face of the mine where loading machines are used and on a trolley haulageway in which there may be wreckage of a trip of cars accompanied by short circuiting of a trolley wire, or, of a power line, as occurred in a slope mine in Alabama. Ignition may also occur by short circuiting an electric lighting system, as was claimed to be the cause of a disastrous explosion which originated in intake air close to the mouth of a slope mine in the Pittsburgh district and followed immediately the breaking down of a coal conveyor which ruptured electric lighting wires at the foot of the slope.

2. The effect of confinement on ignition - that is, whether the coal-dust is present in narrow places such as headings, or in wide places such as rooms.

3. The minimum quantity of coal-dust that can be ignited with production of a self-sustained explosion, and the variation thereof with size of dust, strength of source of ignition, and position of the dust with respect to the perimeter and cross-section of the passageway. The position of the dust determines the ease with which a dust cloud is formed by a given source.

(B) Propagation of coal-dust explosions:

Grading or rating of the relative explosibility of different coal-dusts, or of the same coal-dust under different conditions, has been based on the minimum amount of inert or noncombustible material that must be present to prevent propagation of flame over distances fixed by certain standard test methods that have been developed. Variations in the relative explosibilities so determined have been studied extensively.

4. The relative explosibility of coal-dusts prepared from samples brought from different coal-mining districts of the United States, Canada, and Great Britain. Correlation of the results of these tests with the chemical composition of the coals has shown the effect on explosibility of variation in the percentage of volatile matter, ash, and moisture of the coal itself. Other things being equal, the higher the volatile combustible ratio, the more easily in general does the dust ignite and propagate an explosion.

5. The reduction in explosibility caused by extraneous moisture as compared with that produced by extraneous dry inert material.

6. The increase in relative explosibility caused by the presence of small amounts (usually 1 or 2 percent) of firedamp. In these tests natural gas is piped to the fan and liberated at the intake orifice thereof. It is mixed with and carried by the air current through the mine.

7. The effect on explosibility of variation in the relative positions of coal and inert dust prior to ignition - that is, whether the dust is on the floor, ribs, or timbers.

8. The effect on explosibility of size (a) of the coal-dust particles and (b) of the inert dust particles.

9. The effect on propagation of varying the quantity of dust present per linear foot of passageway or of dust-cloud density per cubic foot of space. In connection with this there have been determinations of the degree of concentration or

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density of coal-dust in air most favorable to propagation of flame and, consequently, requiring the greatest proportion of inert materials in a mixture to prevent propagation. Variation in the density giving this optimum effect caused by altering the source of ignition has been studied, as well as the effect of large quantities of dust near the source of ignition, known as superdusting, whereby development of a self-sustained explosion may be prevented under exceptional conditions. Large quantities of dust along the path of an explosion may retard but do not stop it.

10. The effect on explosibility of dust of the degree of wetness of the walls of the passageway and of the humidity and temperature of the mine air.
11. The effect, at the time of ignition, of movement of ventilating currents of different velocities and direction with reference to the point of ignition.
12. The effect on propagation of a coal-dust explosion of turns and curves, changes in cross-section, and of obstacles such as mine cars in the path thereof.
13. The effect of branches from the passageway traversed by a coal-dust explosion giving opportunity for release of pressure ahead of and (or) behind the explosion.
14. The effect of dustless and watered zones of various lengths in the path of a coal-dust explosion.
15. The effect on propagation of an explosion of altering the point at which it is initiated - that is, whether at the face of a mine in a room or heading, in a passageway at a distance from the face, or near the mouth of the mine.

Quantitative determinations have been made on many of the foregoing problems, particularly as regards the effect of chemical composition of the coal, gas in the air current, extraneous moisture, size of dust, and quantity of dust present.

(C) General phenomena of explosions:

The progress of a coal-dust explosion in a mine is attended by a complex series of physical and chemical phenomena. Comprehensive data on some of these have been given by the recording instruments used in tests as follows:

16. The velocity of the shock wave sent out by the source of ignition.
17. The chemical composition of gases ahead of, in, and behind the flame as determined by analysis of samples collected by automatic samplers.
18. The rapidly fluctuating pressures produced by explosions as recorded by manometers placed at different points in the passageways traversed by the flame.
19. The velocity of the flame at different points as measured by the fusion of tin foils in electric circuits and its relation to pressure waves.
20. The extent of the flame as measured by burning of safety matches and by photographic means.
21. The direction of movement of air and burned gases forced through the passageways by the pressures produced during the explosion.

Prevention of Coal-Dust Explosions

Many methods for prevention of coal-dust explosions have been tested, including:

22. Humidifying as by steam.
23. Wetting the coal-dust.
24. Rock-dusting.

Of the foregoing, humidifying the mine air was found to have no practical effect. Wetting was effective if the coal-dust was so wet as to be in a muddy condition, but in practice it was found not possible to wet with sufficient frequency to prevent explosions; this fact

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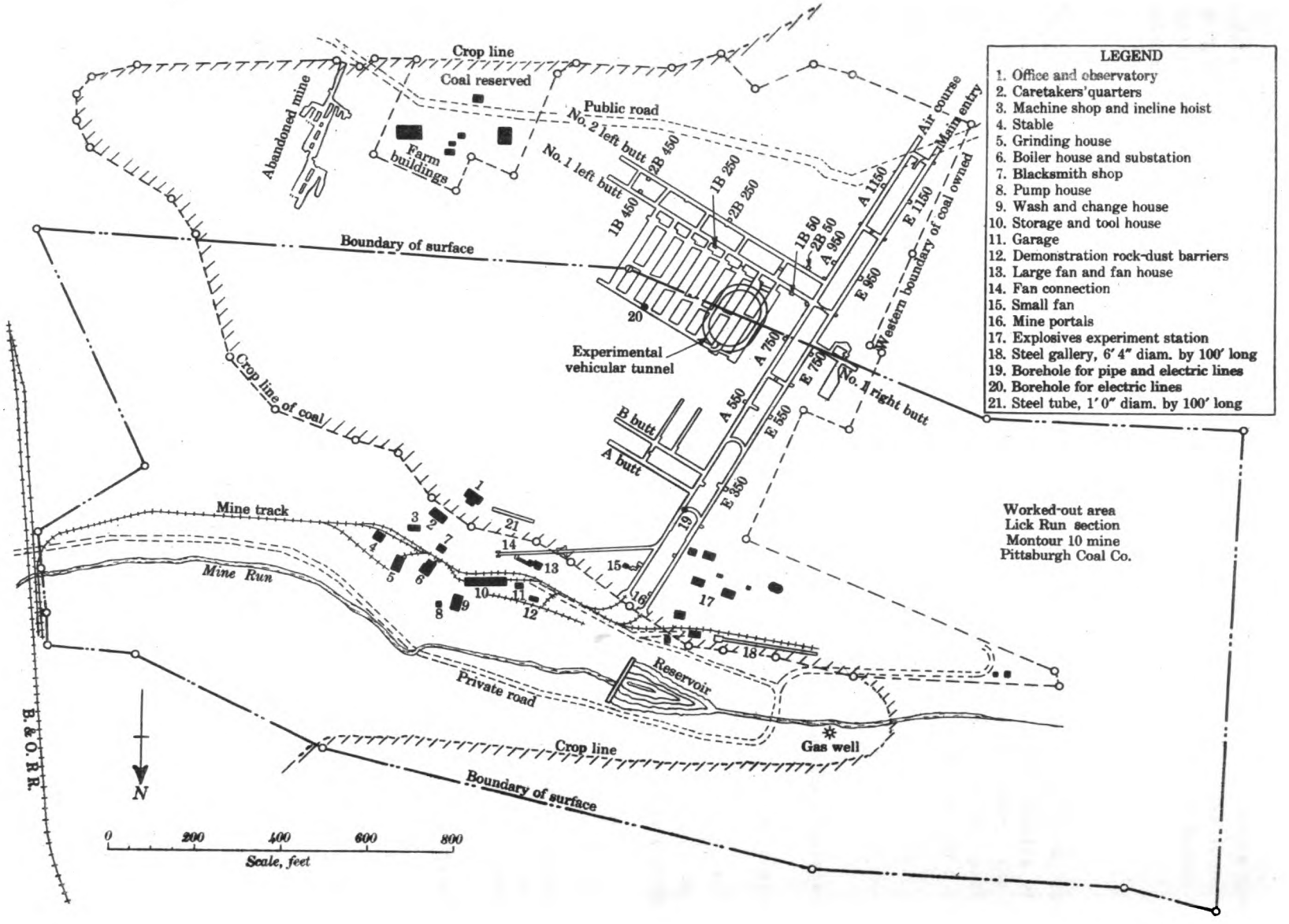

Figure 1.— Plan of Experimental Mine property showing principal surface features and extent of underground workings as of June 1933.

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was determined not only in the Experimental Mine but also in commercial mines where the wetting system was employed yet explosion disasters occurred. Rock-dusting was found to be effective and since 1913 has been advocated by the United States Bureau of Mines, to be supplemented by watering at the face of the mine.

Limiting or Stopping Incipient Explosions by "Barriers"

25. "Barriers" of various kinds have been tested, including water barriers, but only "rock-dust barriers" of specific character and with a minimum loading of rock-dust were found to be effective in stopping incipient explosions. The Bureau of Mines has issued a list of barriers of approved character for particular positions but regards them as only supplementary defenses and not as a substitute for rock-dusting.

Firedamp Studies

26. The diffusion of methane as it enters from the face of the mine simulated artificially by the placing of pipes from which gas issues.
27. The effect of ignition of gas (natural gas) on causing ignition of coal-dust:
    (a) When undiffused,
    (b) When partly diffused,
    (c) When thoroughly mixed with air.
28. The length of flame produced by a gas-air mixture when ignited in a heading.

Ventilation Studies and Tests

29. Use of auxiliary blowers and tubes in a heading giving off gas at the face and the increase in concentration of gas in the air in a heading caused by recirculation of air when the intake of the blower is fed partly by the return air issuing from the heading.
30. Measurement of the frictional resistance of a ventilating current caused by:
    (a) Rough surfaces in a mine passage,
    (b) Turns,
    (c) By obstacles, such as cars.
31. Ventilation of vehicular tunnels. An extensive series of tests was carried out in cooperation with the New York - New Jersey Tunnel Commissions, with a view to a proper design for what was subsequently known as the Holland Vehicular Tunnel under the Hudson River. The study was carried out in a specially constructed passageway, elliptical in plan view (as indicated in fig. 1), divided in cross-section into an underduct for intake air, a roadway in which automobiles were run, and an over-duct for return air. This method of ventilating a long tunnel, known as the transverse system of ventilation, was adopted after successful testing in distinction to the previous customary longitudinal system of ventilation. This novel method of tunnel ventilation has been used in various vehicular tunnels in the United States and is to be employed in one which is now under construction in Belgium. The principle of it, by employment of ducts, could be used with great safety in the driving of all long tunnels, such as in those for water supply of cities.
32. Physiological tests of inhaling small percentages of carbon monoxide in the Experimental Mine supplementing laboratory testing.

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In addition to the elaborate tests of the movements of the ventilating currents, by the new method of tunnel ventilation, physiological tests were made of the effects of small amounts of carbon monoxide coming from the exhaust of automobiles upon the drivers of the automobiles and others taking part in the tests. As many as 55 persons were employed in a single test.

Mine-fire Extinguishment

From time to time tests have been made of various kinds of fire extinguishers and fire-extinguishing methods. Included among these were:

33. Tests to determine the trajectories of streams of water at a pressure which would permit the handling of the hose and nozzle by one man in a mine passage.
34. Tests of the relative effectiveness of different chemical extinguishing sprays and gases.
35. Rock-dusting by shoveling rock-dust on a mine fire in its initial stage, a method which has proved very successful.

Tests of the Deterioration of Explosives

36. Tests of the deterioration of explosives when stored in mine air are carried on from time to time in certain parts of the mine distant from the entries in which coal-dust explosions are made. These tests are made by the explosives testing section of the Bureau.

Strength of Mine Stoppings

37. An extensive series of mine-stopping tests was conducted in cooperation with the Bureau of Standards. The preliminary tests were carried on in a surface chamber at the Bureau of Standards but the major tests were conducted in the Experimental Mine. This testing was done to furnish information in the administration of regulation of coal mining on the public domain, which calls for stoppings which will resist specific explosion pressures at boundary pillars where openings had been made. The results of these tests determined that a plain concrete stopping acting as a flat arch, when of a certain ratio of thickness to span, would give the most practical form of mine-stopping construction.

Compressibility of Coal

40. As an outgrowth of the tests of the strength of stoppings acting as flat arches and pressing against the coal abutments, testing was conducted on the compressibility of coal in place:
    (a) Horizontally, which concerns the abutment strength, and
    (b) Vertically, which has relation to the strength of the coal as a pillar.

A progress report has been issued as Technical Paper 527.

Ground Movement and Subsidence Studies

41. In connection with the extraction of pillar coal along a retreating breakline in the adjoining coal mine, monuments were established and surveys made to determine -

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(a) Whether or not in shallow workings there was a "draw" over the pillar coal, and

(b) Whether or not there was a "draw" over the barrier pillar adjacent to the Experimental Mine.

The answer was negative under the conditions in both cases, which, however, might not be the case where mine workings were deeper below the surface.

Prevention of Falls by Guniting

42. The effect in preventing weak mine roof from weathering and falling is shown by the practical and successful use of guniting for preventing the Experimental Mine entries from caving. This guniting method of protection from oxidation of mine walls was first used and developed in the Experimental Mine in 1913.

World-War Studies

During the World War a number of special studies were carried on at the request of the Chief of Engineers of the Army.

43. In the course of testing the use of the French military geophone, geophone was greatly developed by a physicist of the Experimental Mine, and following the war was employed for various purposes, as for example, to detect leaks in compressed-air lines, water mains, etc.

44. Studies were made with the improved geophone of the distance at which sounds of working in adjacent places with pick, drill, or machine could be heard through solid strata. The information obtained was primarily for military mining but was later found valuable in certain instances in metal mining in making connections between mine headings, as from shafts or winzes, which were so tortuous that precise instrumental surveys were difficult.

Helium Storage

45. The storage of helium underground under high pressure for military purposes in disused or specially constructed mine chambers was considered a possibility, and, at the request of the War and Navy Departments, tests were made in the Experimental Mine. However, later it was decided that storage on the surface in high-pressure steel containers was preferable.

Safety Training and Demonstrations

46. One of the most practical educational uses of the Experimental Mine has been as a training place for the candidates for State inspectorships and mine foremen's certificates. The mine passages and arrangements are such that temporary defects in ventilation and other mine safety features can be made. The mine is then examined by candidates, who are requested to make notations of those defects they observe, including such data as results of tests for gas.

Demonstrations

47. Demonstrations of the explosibility of coal-dust and the beneficial effects of rock-dusting and other features involved in safety in mines are made to groups

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of mining men, as for example, to those having coal-dust under test, or when they are attending meetings of institutes or safety societies in Pittsburgh. Among other demonstrations usually a large explosion test is shown; sometimes the explosion is arranged so as to burst out of the two entrances to the mine with great violence, projecting cars and timber across the valley. Such explosion demonstrations have been witnessed by thousands of mining men. The effect of rock-dusting is usually shown by rock-dusting one or more parts of the mine, through which, in consequence, the explosion does not travel, or the effectiveness of approved types of rock-dust barriers may be demonstrated. At times of such demonstrations other mining hazards are shown such as "mud capping" shots of explosive and direct ignition of coal-dust in air by electric arcs or by an open light.

DESCRIPTION OF PROPERTY, SURFACE BUILDINGS, AND EQUIPMENT

The boundaries of the property and the principal surface features are shown on Figure 1, together with the underground workings and the crop line of the coal. The surface, of which there is 77 acres, is roughly rectangular in shape with the principal axis in an east-west direction. The northern and southern boundaries are at the tops of hills which enclose the valley of the small stream shown as "Mine Run" on the figure. This stream is dammed just west of the mine portals to form a reservoir of boiler water. A private road, which follows the grade of the stream , joins a highway about 350 feet east of the point where it crosses the right of way of the Baltimore & Ohio Railroad.

The coal bed outcrops along both sides of the valley; that part owned by the Bureau is on the south side and has an irregular crop line, as shown in the figure. The south crop line of the government coal is in the valley south of that of Mine Run. The coal under a group of farm buildings in this valley has been reserved. Just east of these buildings is a small abandoned country mine which has been surveyed as far as still open, but of whose history little is known. It has not been worked for more than 40 years.

The mine buildings are grouped to the east of the portals; they have been numbered on figure 1 and their designations tabulated. At the southeast corner of the group is the office and observatory (1). In the latter are housed all instruments used in recording phenomena of coal-dust explosions that are not installed in the mine; also all control and operation during an explosion test are centered there. Immediately below the office are the caretaker's quarters (2) and below these is a small machine shop (3) in which is housed a hoist for handling mine cars on the incline between the mine and railroad levels. Only animal haulage is used elsewhere and the most easterly building (4) is a stable.

Turning westward one encounters next the grinding house (5) in which are crushing and pulverizing equipment and storage bins for dust. All dust mixtures used in explosion tests are prepared in this building. The next building (6) is the boiler house and substation. Steam is used only for heat in cold weather and overhead lines run to all the important buildings, including the explosives testing plant of the Bureau situated west of the mine. Electric power for both the mine and the explosives plant are obtained from a public utility company's, 2,200-volt line which traverses the property as shown; a short branch terminates in a bank of transformers back of the substation. From this there is available for operation and experimental purposes electric currents of 110 and 220 volts d.c., 110 and 220 volts single-phase a.c., and 440 volt three-phase a.c.

All lines used in explosion testing in the mine pass through the observatory where the controls are located, then go to a set of disconnecting switches on the surface near the

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portals and finally enter the mine through a borehole (19) near the junction of the aircourse and the first crosscut to the main entry. Power can also be taken into the mine through a borehole (20) at the face of No. 6 room off No. 1 left butt entry. The substation also houses an air compressor from which pipe lines run to the grinding house, observatory, and into the mine, where compressed air is used in the test work, principally in cleaning the explosion test zone.

Immediately south of the boiler house is a blacksmith shop (7). Northwest of it is a small pump house (8) built over a drilled well from which the domestic water supply is obtained. A second pump takes water for general purposes from the surface reservoir which is formed by damming up "Mine Run." Separate tanks sunk in the ground on the hill are used for storing water obtained from these two sources of supply.

Adjacent to the pump house is a wash and change house (9) and above it is a storage and tool house (10). At the west end of this building is a garage (11) and a set of rock-dust barriers (12) erected on the surface for demonstration purposes. Across the mine track is the large main mine-ventilating fan (13) with arrangements for reversing the ventilating current. The fan is connected by a 6-foot diameter steel tube (14) to a branch entrance of the air course. This arrangement allows only a fraction of the force of an explosion in the mine to proceed toward the fan, and there are a number of additional pressure releases on the steel tube and its connection to the fan casing. A small auxiliary fan (15) is connected to the air course through a shallow shaft not far from the portal. Ample pressure-releases are provided for this fan also.

Massive concrete portals of the mine (16) are at the mouths of the main entries. The underground layout has been discussed previously. The portion of the property west of the mine portals is occupied by the Explosives Experiment Station (17), a section of the explosives division of the Bureau. All large-scale tests of explosives are conducted there. One piece of equipment is a steel tube or gallery (18) 6 feet 4 inches in diameter by 100 feet long used primarily in permissibility testing, but available for tests of coal-dust when only small quantities are at hand or there are other reasons for its use in this manner. There is also a tube (21) 1 foot in diameter by 100 feet long installed just west of the observatory for experiments on the propagation of flame in mixtures of natural gas and air.

Passing down the valley of Mine Run is a natural-gas line which collects gas from a number of wells west of the Experimental Mine property. A branch of this line makes available for testing purposes a natural gas of high methane content at both rock and ordinary distributing pressures. Tests have shown that the explosive properties of this natural gas are much the same as those of pure methane, the principal difference being that the limits of explosibility of the natural gas mixed with air are slightly lower.

RECORDING INSTRUMENTS

The nature of the phenomena occurring in a coal-dust explosion can be studied on a large scale only through the use of recording instruments. Some of those at the Experimental Mine were copied from instruments in use at the original French testing station at Liévin and were subsequently modified as required. Others were developed as the work progressed. The classes of records that have been obtained to date are velocity of flame, extent of flame, time-pressure records at different points, composition of gases ahead of, in, and behind the flame, direction of movement of bodies of air and burned gases, and time of movement of different objects such as parts of barriers.

All of these involve the accurate measurement of small intervals of time and chronographs are employed for this purpose. Briefly, these consist of brass drums around which are glued sheets of metallic-surface paper which are covered in turn with camphor smoke. Thirty-

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four celluloid pen tips arranged in groups rest on the paper and trace lines in the smoke when the drums are revolved; the pens are mounted on a carriage having a longitudinal movement so that the lines are spirals. The pen tips are attached to the armatures of small electromagnets which when energized impart a movement of about 1 mm. to the tip in a direction at right angles to that of the spiral trace, thus making a short cross-mark which permits measurement of time of the respective movement.

To record any event it is merely necessary to arrange that it will make or break the current in one of the pen circuits. It is possible to record 27 independent and simultaneous events. Normally only one event can be recorded per pen; it is possible to record more than one only when their sequence is invariable and they alternately make and break the circuit. One pen on each chronograph is operated by a tuning fork giving a record in hundredths of seconds from which thousandths are readily estimated. Zero time is taken as the moment at which the explosion is initiated and is obtained by having the source of ignition break the current in one circuit. The normal length of record of an explosion is about 10 seconds; after it is obtained, the papers are suitably marked, the smoke set with shellac solution and the sheets removed for computation.

The chronographs are housed in the observatory. From them leads a 31-wire cable containing a wire for each pen, a common return, a telephone circuit, and a pair of wires reserved solely for firing shots or initiating explosions by other means. This is paralleled by a second 4-wire cable carrying light and power to the instruments placed in the mine. These cables pass above ground to a borehole, as mentioned above, and in the mine are carried in conduits cemented in the ribs to the various stations where instruments are located. Large shelters for instruments are provided at 200-foot intervals throughout the mine; they are indicated on figure 1 by the figures E 350, E 550, A 550, etc. Smaller shelters used only in determining the velocity of flame are at intermediate points.

Velocity of flame is determined through the fusion of small strips of tin foil set in recessed blocks at 100-foot intervals. Fusion of each foil breaks a circuit on the chronograph, and velocities are computed from the time intervals. These foils also serve to determine length of flame to the nearest 100 feet, but a closer measure thereof is needed. This is obtained photographically by the action of the light of the flame on circlets of photographic bromide paper placed in suitably designed receptacles fastened to the roof at 25-foot intervals.

Pressure is measured by means of a specially-designed manometer in which the pressure causes deflection of a steel diaphragm. This diaphragm is connected to a focusing mirror and movement thereof causes a spot of light to travel across a photographic film rotated by a motor. The pressures corresponding to different deflections are known and an auxiliary device makes simultaneous time records on the films and on one of the chronographs in the observatory. It is then possible to translate the records into coordinates of time and pressure and relate them to the travel of the flame recorded by the tin foils.

There is also a tube with lens connected to each manometer so that the light of the flame of the explosion as it passes is recorded directly on the photographic film with the pressure records, thus indicating the duration of this flame on the same time basis.

Differences in pressure between points along the passageways cause violent movement of air and burned gases. The direction of these is determined by the movement of a small vane attached to an instrument so that the vane normally hangs in a neutral position. Movement of the vane in either direction is recorded on the chronographs. It would be desirable to determine the velocity as well as the direction of gas or air movement, but no thoroughly reliable instrument has been devised as yet to supplement the manometer records.

A complex series of chemical reactions occurs in the flame, the oxygen of the air combining with combustible matter of the coal-dust to form gases which are mixed with

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products of distillation of the coal-dust. An automatic device has been used for snatching samples of the gases for subsequent analysis. It consists of an evacuated brass bottle of which one end is closed by a valve and the other is sealed with a thin, flat glass plate. A mechanism tripped by an electric current interrupted at a certain distance inby the sampling device, is rotated spirally, the glass is driven against breaker prongs and then, after an interval of one twentieth of a second, against a rubber stopper which traps the sample that has entered. The sample is subsequently transferred through the valve to a glass container and sent to the laboratory for analysis.

SOME PHENOMENA OF EXPLOSIONS

Use of the above instruments in nearly 1,500 explosion tests in the Experimental Mine has given definite knowledge of many of the phenomena that are a part of coal-dust explosions.

The Shock Wave

Firing a shot or a considerable fall of roof in a mine produces a concussion which spreads through the air at the velocity of sound - in fact it is this wave which gives one the sound of the shot or the fall. The velocity of this concussion is about 1,100 feet per second in the Experimental Mine, but is affected by the density of the air and would be different in deep mines or at high elevations. When a shot blows out, the concussion is very violent and has great power to raise dust and form a cloud of it in air. A blow-out shot of 4 pounds of FFF black blasting powder is used in two of the standard test methods employed in the Experimental Mine to initiate a coal-dust explosion. The concussion produced by this shot has been termed the "shock wave." With the cannon in a fixed position the time of its arrival at any given point varies not more than 0.003 second, and it may be that these variations are errors of determination. The pressure of the wave diminishes as it travels and attenuation is particularly marked at points where expansion into branching passageways takes place. It is capable of producing a dense dust cloud in the vicinity of the cannon, but it is doubtful if this power is retained for more than a few hundred feet of travel.

If ignition of coal-dust follows the initial shock wave there is a rapid succession of air waves from the explosive combustion accompanied by a bodily forward movement of the air as a column. These waves and forward movements continue as far as the coal-dust explosion propagates, stirring up the dust ahead of the flame. It is this forward movement with its accompanying waves raising coal-dust that makes spread of a coal-dust explosion possible.

When a coal-dust explosion is initiated by a gas explosion there is no strong initial shock wave unless it is produced by the agency that ignites the gas. Otherwise the first pressure waves are produced by the burning gas; these have all the properties of shock waves and are accompanied by the violent forward movement of the air. When a preformed coal-dust cloud is ignited by an electric arc, the first pressure waves, following the more or less weak concussion which stirs up the coal-dust, come from the combustion and these also have the properties of shock waves.

Flame Velocities

Whereas the initial velocity of a shock wave is 1,100 feet per second or more, depending on the conditions present, the initial flame velocity in a coal-dust explosion will rarely exceed 500 feet per second and may be as low as 100 feet. The flame velocity depends primarily on rate at which combustion can proceed through the dust cloud present, and secondari-

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ly on the movement of air carrying the dust cloud along the passageway. If conditions are unfavorable the flame may slow down and die out. The lowest flame velocity ever recorded in the Experimental Mine in a self-sustained dust explosion was 30 feet per second (20 miles per hour, approximately). More commonly the minimum velocity has been between 50 and 100 feet per second. Under favorable conditions the flame accelerates rapidly and velocities of 1,000 to 1,500 feet per second may be attained in 1 second or less. There is some uncertainty as to the maximum velocity attainable in a coal-dust explosion. Velocities in excess of 3,000 feet per second (34 miles per minute) have certainly occurred in the Experimental Mine, and 6,000 feet has been indicated, but the possible experimental errors become so large at such high velocities that considerable uncertainty exists concerning them. At any velocity in excess of 1,200 feet per second the flame can overtake the initial shock wave if a sufficient length of passageway is present, and will then proceed through a dust cloud formed at its front by the pressure of the expanding gases of combustion, projecting its own waves sufficiently ahead to stir up the amount of coal-dust necessary for propagation of the explosion.

Shape of Flame

The flame of a coal-dust explosion in a mine passageway is pointed with the point somewhere near the center of the passageway. Doubtless the actual shape varies considerably from moment to moment, but the general pointed shape is retained. In a weak slow explosion the point is sharper and combustion may not extend to the walls. Some experiments have indicated that this point may be as much as 100 feet long and combustion may be taking place over a length of 300 feet or more at any one instant. As the flame velocity increases, the point of the flame will become blunter and the total length of flame will be shorter because of the more rapid rate of combustion laterally as well as forward. In this connection it should be remembered that the total amount of combustion is limited by the quantity of oxygen present, but possible variations in this quantity are small compared with those of flame velocity and rate of combustion.

Pressures Produced by Coal-dust Explosions

The pressures produced by burning coal-dust at the time of initiation of an explosion are low and usually of the order of 3 to 5 pounds per square inch unless the source of ignition has been exceptionally strong. Should conditions be unfavorable, no higher pressures will be produced during the course of the explosion. On the other hand, with favorable conditions pressure will rise rapidly and reach 25 to 30 pounds per square inch in less than 1 second. Pressures of 60 to 70 pounds are common when good clouds of relatively pure coal-dust are formed.

Theoretically the maximum pressure obtainable with an atmosphere pressure is 142 pounds per square inch, but as the explosion develops, precompression of air occurs ahead which may be several atmospheres; then if there is sufficient coal-dust present, which there nearly always is in a coal mine, the pressure of the explosion is correspondingly increased and extreme violence may result. It is characteristic of explosions in dusty coal mines unprotected by rock dusting that the violence of the explosion increases as it travels. On the other hand, when by rock dusting or for other reasons the flame is extinguished, the pressure rapidly drops.

The highest pressure recorded in Experimental Mine tests was 127 pounds obtained with pure dust of a low-volatile bituminous coal. Higher pressures have been present, as manometers have been wrecked by them. As a rule, the higher the pressure, the less its duration.

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Pressures of 50 pounds per square inch or more usually last only a few hundredths of a second and approximate a hammer blow.

Chemical Reactions Occurring in a Coal-Dust Explosion

Some knowledge of the chemical reactions taking place in the flame of a coal-dust explosion has been obtained from the composition of samples of gas taken by the automatic samplers described above. These samples were collected at a point 350 feet from the origin of an explosion, and the flame was well developed before the sampling point was reached.

If one can imagine himself stationed at the point where the samples were collected, with the flame approaching him along the passageway, the first question is whether radiant heat of the flame is having an effect in advance of that flame. No positive evidence of such an effect has been obtained. If it is present the distance over which it is effective is too short to permit detection; a dense dust cloud likely absorbs or screens the heat.

Simultaneous samples collected close to the rib and at a point 27 inches therefrom have shown that vigorous combustion may be in progress at the latter point while little or none is occurring at the former. This is due to the pointed shape of the flame described above. In a weak explosion a thin layer of relatively pure air may remain close to the rib, probably embraced in a dense layer of the suspended dust, until after the flame has passed, while in the center of the entry the oxygen content of the air has been reduced to not over 2 or 3 percent with an accompanying production of 10 or 12 percent carbon dioxide and appreciable quantities of carbon monoxide and distillation products from the coal-dust.

In a rapid and violent explosion of dry dust, combustion is much more complete and the oxygen content of the entire body of the air may be reduced below 1 percent. Carbon monoxide will be present in quantities of 4 percent or more, but the quantity of carbon dioxide is reduced at the same time. This indicates that part of the carbon monoxide is produced by reaction of carbon dioxide with hot carbon after the primary combustion has taken place. The effect of higher temperatures or more prolonged heating is shown by the presence of larger quantities of methane and hydrogen distilled from the coal. Appreciable quantities of ethane and unsaturated hydrocarbons are found at times.

When the coal-dust taking part in an explosion is damp or wet, a new chemical reaction is possible; namely, that between steam and hot carbon, commonly called the water-gas reaction. The hot carbon reduces the steam, forming large volumes of carbon monoxide and hydrogen. The extent to which this reaction can take place is shown by one sample taken in the flame of a strong explosion of wetted coal-dust. This sample contained 0.8 percent oxygen, 11.7 percent carbon monoxide, 6.2 percent hydrogen, 4.2 percent methane and ethane, and 8.4 percent carbon dioxide. The methane and ethane came entirely from the coal-dust, as there was no gas in the air current prior to the explosion.

Chemical reactions practically cease after flame has passed, where upon the gases cool. Any change in composition is then caused by dilution with fresh air from points not reached by the explosion, or by absorption of some of the gases into the coal-dust or coal walls. In any case the remaining gases will be irrespirable until full ventilation is restored.

Coking Phenomena

Coke found after coal-dust explosions in mines is the residue of partly consumed dust. Observations after tests in the Experimental Mine have shown that the quantity of coke found after an explosion depends a great deal on the coking properties of the coal being tested. Large quantities are found after tests of Pittsburgh coal dust, and none after tests of feebly coking or noncoking coals, such as subbituminous coals. A slow explosion is favorable to the

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production of coke, as the dust is exposed to heat for a longer period of time and there is less violence tending to destroy masses of it that may be formed. In apearance the coke may vary from gritty granular material to bright shiny sheets from which nearly all the volatile matter has been expelled. Quantities of individual coke bubbles are sometimes found on the floor; these are so light that they sometimes drift with a strong air current. When the flame lingers for a considerable period at one point, as where there may be accessions of air from adjacent spaces not traversed by the explosion proper, exposed coal ribs may be coked and blistered in place. This is especially apt to be the case in gassy areas. There has been sufficient variation in the position of coke deposits in different tests to make difficult the recognition of any system of formation by which the origin of an explosion in a commercial mine could be deduced from observations of the coke deposits found afterward.

In general, however, near the origin of a dust explosion the coked dust is found facing the source of explosion, when the explosion accelerates it is more apt to be on the reverse side of timbers or projections, and as an explosion dies away it is found on the facing side of projections.

Much less coke is found after violent explosions of coal-dust, even where the coal has highly coking chaacteristics. This may be due to more complete combustion or it may be that conditions are less favorable to its formation; also the chances that large masses will be broken up by subsequent violence are much greater.

Movement of Objects by an Explosion

In Experimental Mine tests many observations have been made of the movement of objects whose exact position was known before the explosion. The forces that are exerted in violent explosions are enormous and the destruction caused frequently resembles that following a blast of explosives. Knowledge of the mechanism by which destruction is accomplished and heavy objects carried long distances is qualitative only. Strong pressure waves can cause great destruction, but a single wave can cause only limited movement of the resulting debris. Movements of considerable magnitude are probably caused largely by columns of air or burned gases propelled through the passageways at extremely high velocitiies; these pick up and carry objects which sometimes weigh hundreds of pounds. The cause and power behind these movements lies in the rapid combustion of coal-dust in air - that is, in the zone in which combustion is proceeding actively. When an explosion is traveling freely along a passageway and is not dying out, the pressure in the flame produced by the intense heat is greater than that ahead or behind it. Because of this a horizontal column of air is forced ahead of the advancing combustion zone at high velocity and, similarly, a column of burned gas is propelled backward from that high-pressure zone toward the origin of the explosion. An object picked up and carried by the air blast ahead of the explosion will frequently be overtaken by the flame, which travels at a higher velocity and with rising pressure; the direction of movement of the object is reversed when the flame passes it, and, if the explosion continues strongly, it may eventually come to rest considerably nearer the origin of the explosion than it was originally. This has happened many times in the Experimental Mine. Fragments of shelving originally installed 200 to 400 feet from the face of the main entry have been found in a heap at the face of the entry completely burying the cannon used to initiate the explosion at that point. Loaded mine cars have been overturned and thrown toward the explosion origin.

At times the manometers record strong pressure waves traveling backward through the burned gases. These appear to originate in the flame and travel with the velocity of sound under the conditions of density and temperature of the after gases then and there obtaining. They have been called "retonation waves" in Experimental Mine terminology. In a mine there cannot be precise distinction between waves traveling at the velocity of sound as determined

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by the temperature and pressure of the atmosphere traversed, and movement forward or backward of columns of gas caused by pressure differences. The zone of combustion sends off waves continuously. All sorts of combinations result when these waves are reflected from the rough walls and closed ends of passageways; also their velocities with reference to a fixed point change with the temperature, pressure and bodily movement of the gas through which the wave travels. It is only when a wave of unusual amplitude appears that one can trace it as it is recorded on successive manometers.

After an explosion is extinguished there is an inrush of air to fill the partial vacuum created by cooling of the hot gases. This inrush may carry light objects for considerable distances and further complicate the evidences of movements of material. It is clear, therefore, that the position of objects after an explosion cannot always be relied on to determine the point of origin of the explosion; final movement may be toward the origin or away from it, depending on how the explosion developed. It requires careful study in retracing the path or paths of a mine explosion disaster to evaluate the contradictory evidences of violence.

Relative Explosibility of Coal-Dusts

The relative explosibility of a coal-dust is measured by the proportion of incombustible material that must be present with it in a mixture to prevent propagation of flame under standard test conditions. When dust of a given coal is tested the quantity of incombustible material required to prevent propagation depends on the size and quantity of dust present, the strength of the source of ignition, the ease with which a cloud of the dust can be formed, and the configuration and physical condition of the passageways in which the tests are made. Small percentages of inflammable gas in the air current add to the explosibility of coal-dust, for the flame then travels through a mixture of coal-dust, gas, and air. It has been found possible to relate the explosibility of different coal-dusts to their volatile matter content expressed on a moisture and ash-free basis. The lower the volatile content, in general the less explosive the dust; for example, dust of the true anthracites of eastern Pennsylvania (i.e., with a volatile-total combustible ratio, of 5 to 9.5 percent) will not propagate an explosion. Semi-anthracites having a volatile ratio of 12 to 14 percent are on the border line of explosibility in the absence of gas. The dusts of coals of higher volatile content are definitely explosive.

Inflammable gas (firedamp) in the air causes an increase in the explosibility of a coal-dust cloud suspended in that air. The increase is in proportion to the amount of gas present, but its exact rate depends also on the relative explosibility of the coal-dust in the absence of gas. As a result of Experimental Mine tests the additional amount of inert material that must be kept in coal-mine dust to offset the presence of 1 or 2 percent firedamp in the air can be predicted with some accuracy without resort to special tests each time information is wanted.

The foregoing shows that determinations of explosibility of coal-dusts made in the Experimental Mine are relative and not absolute. The proper basis of correlation of the different factors that affect relative explosibility is their effect on the rate of production and dissipation of energy in the zone of combustion that supplies the driving force of the explosion. This can be done qualitatively, but experimental difficulties make a quantitative correlation well-nigh impossible, however, for practical mining application, the relative determinations are sufficiently precise to permit, for example, specifying the amount of rock dust or inert dust that is required to prevent the initiation or propagation of a coal dust explosion.

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LABORATORY TESTING OF THE INFLAMMABILITY OF COAL-DUST

From its inception the Bureau has sought laboratory methods which could replace the more expensive testing carried on in the Experimental Mine. A summary of this work has been issued recently (see Bulletin 365 listed at the close of this paper). Originally attempts were made to correlate explosibility with pressure produced on inflammation of a small quantity of pure coal-dust in a closed vessel. This line was pursued for a number of years until the evidence accumulating from tests in the mine became overwhelming opposed to it. The next general line of procedure was use of laboratory "galleries" - devices designed to simulate a mine passageway on a small scale. Experimenters who endeavored to correlate explosibility with length of flame produced in a gallery were not successful. However, it is believed that a gallery could be devised in which the amount of incombustible required to suppress flame in a mixture could be determined just as it is in the Experimental Mine. At present, work is being carried on with laboratory furnaces following a method developed by the Safety in Mines Research Board of Great Britain. A weighed quantity of dust is blown downward through a vertical furnace; if it is inflammable, flame appears at the bottom of the furnace. The minimum quantity of added incombustible material required to suppress the flame is then determined. It has been found possible to arrange this test to give results comparable with those obtained in the Experimental Mine under certain fixed conditions. However, it appears unlikely that this, or any other laboratory test can completely supplant the mine; rather, they will be valuable auxiliaries to it. The present laboratory test has shown its value in giving information on the explosibility of coals and mine dusts when only small samples were available. It is also of use in investigating the explosibility of other mineral dusts like those of gilsonite and sulphur, and also of metallic dusts such as aluminum; many serious explosions of such dusts have occurred in industrial plants.

CONCLUSIONS

The foregoing paragraphs have traced the history of the Experimental Mine and the investigations conducted therein of the explosibility of coal-dust, and have given a brief account of related investigations made there. Studies of the explosibility of coal-dust have been the principal work for over 20 years, but, while a great deal of necessary and valuable information has been accumulated, many points involving the complexities of mines are still obscure and require further study. It is doubtful if the work will ever reach a point such that the conclusions drawn can be said to be scientifically final or all the practical questions are answered. Rather, the scope of the work will be determined by the needs of and changes in methods of mining, and investigations will be carried as far as the value of the data warrants. Those in charge of the work have always considered that many lines of investigation dealing primarily with increased safety for miners should be carried on as need of them arises, and a number of such researches have been cited in the foregoing pages. They look upon the Experimental Mine as a large-scale laboratory in which problems in mine safety can be investigated under limits prescribed only by the facilities available and the nature of the information desired.

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SELECTED BIBLIOGRAPHY RELATING TO TESTING WORK OF THE EXPERIMENTAL MINE SECTION

Coal-Dust Explosibility, Prevention, and Limitation Methods

Bureau of Mines Publications

Bulletin:

20. The Explosibility of Coal-Dust, by G. S. Rice and others. 1911. 204 pp. Reviews data obtained from gallery and laboratory testing and mine explosion effects prior to opening the Experimental Mine.

56. First Series of Coal-Dust Explosion Tests in the Experimental Mine, by G. S. Rice, L. M. Jones, J. K. Clement, and W. L. Egy. 1913. 115 pp. Describes the Experimental Mine and its equipment and gives the results of a series of explosion tests.

82. International Conference of Mine Experiment Stations, Pittsburgh, Pa., Sept. 14-21, 1912, compiled by G. S. Rice. 1914. 99 pp. Contains a paper on the Experimental Mine, pp. 33-40.

167. Coal-Dust Explosion Tests in the Experimental Mine, 1913 to 1918, inclusive, by G. S. Rice, L. M. Jones, W. L. Egy, and H. P. Greenwald. 1922. 639 pp. Describes the Experimental Mine and its equipment and gives results of second series of explosion tests.

225. Stone Dusting or Rock Dusting to Prevent Coal-Dust Explosions, by G. S. Rice. 1924. 57 pp. Presents the results of a study of the subject during an investigation of mining conditions in Europe.

268. Coal-Dust Explosion Tests in the Experimental Mine, 1919 to 1924, inclusive, by George S. Rice, J. W. Paul, and H. P. Greenwald. 1927. 176 pp. Describes the third series of coal-dust explosion tests.

353. Tests of Rock-Dust Barriers in the Experimental Mine, by G. S. Rice, H. P. Greenwald, and H. C. Howarth. 1932. 81 pp. Describes tests and summarizes results. Discusses qualities of effective barrier installations in commercial mines.

369. Explosion tests of Pittsburgh coal dust in the Experimental Mine 1925 to 1932, inclusive, by G. S. Rice, H. P. Greenwald, and H. C. Howarth. 1933. 44 pp.

Technical Paper:

84. Methods of Preventing and Limiting Explosions in Coal Mines, by G. S. Rice, and L. M. Jones. 1915. 45 pp. Treats of causes and prevention of explosions and describes rock-dust barriers devised by the engineers of the Bureau.

386. Explosibility of Coal-Dust from Four Mines in Utah, by H. P. Greenwald. 1927. 19 pp. Describes tests made at the Experimental Mine and gives a summary of results.

464. Coal-Dust Explosibility Factors Indicated by Experimental Mine Investigations, 1911 to 1929, by G. S. Rice and H. P. Greenwald. 1919. 45 pp. Classifies and summarizes the knowledge gained from more than a thousand experiments, the details of which have been given in previous reports. Stresses the need of efficient generalized rock dusting to prevent coal-dust explosion disasters.

Report of Investigation:

2606. Tentative Specifications for Rock Dusting to Prevent Coal-Dust Explosions in Mines, by G. S. Rice, J. W. Paul, and R. R. Sayers. 1924. Defines standard rock dust and states in detail what is meant by adequate rock dusting.

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Determination of Inflammability of Coal and Other Mineral Dusts by Laboratory Methods

Bureau of Mines Publications

Bulletin:

20. The Explosibility of Coal-Dust, by G. S. Rice, and others. 1911. 204 pp. Contains a chapter reviewing previous laboratory dust-inflammability tests, as well as those conducted at Pittsburgh station, by J. C. W. Frazer.
50. A Laboratory Study of the Inflammability of Coal-Dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, Jr. 1913. 60 pp. Summarizes the results of tests of the inflammability of a large number of samples of coal-dust from different mines.
102. The Inflammability of Illinois Coal-Dusts, by J. K. Clement and L. A. Scholl, Jr. 1916. 74 pp. Presents the results of a detailed study of coal-dusts collected in the bituminous-coal mines of the State.
365. Laboratory Testing of the Inflammability of Coal and other Dusts Conducted by the Bureau of Mines, by H. P. Greenwald, with a foreword by George S. Rice. 1932. 63 pp.

Technical Paper:

141. Laboratory Determination of the Explosibility of Coal-Dust and Air Mixtures, by J. K. Clement and J. N. Lawrence. 1917. 35 pp. Explains laboratory tests in which pressure developed by combustion of dust is taken as measure of inflammability.

Strength and Compressibility Tests of Coal and Roof Supports and Subsidence from Mining

Bureau of Mines Publications

Bulletin:

303. Tests of Strength of Roof Supports used in Anthracite Mines of Pennsylvania, by G. S. Rice and Charles Enzian. 1929. 44 pp. Review of compressive strength of anthracite and bituminous coals, including coal from the Experimental Mine.
345. Concrete Stoppings in Coal Mines for Resisting Explosions: Detailed Tests of Typical Stoppings and Strength of Coal as a Buttress, by G. S. Rice, H. P. Greenwald, H. C. Howarth, and S. Avins. 1931. 63 pp.
527. Compressibility and Bearing Strength of Coal in Place: Tests of Lateral Compression of Pittsburgh Coal Bed, by H. P. Greenwald, S. Avins, and G. S. Rice. 1933. 12 pp.

American Institute of Mining and Metallurgical Engineers Publications

Recent Research on Ground Movement Effects in Coal Mines and on the Strength of Coal and Roof Supports, by G. S. Rice. Transactions, vol. 101, Coal Division, 1932. pp. 75-106. Includes description of tests in Experimental Mine of bearing

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strength, elasticity, and plasticity of coal-in-place.
Subsidence from Pillar Extraction at Montour No. 10 Mine Adjacent to the Experimental Mine of the U.S. Bureau of Mines, by H. C. Howarth. Tech. Pub. 502. 1933. 8 pp.

Mine and Tunnel Ventilation Testing in Experimental Mine

Bureau of Mines Publication

Bulletin:

285. Coal-Mine Ventilation Factors, by H. P. Greenwald and G. E. McElroy. 1929. 106 pp. Describes tests and gives data on pressure of air losses and various resistance.

Other Publications

Recirculation of Air and Mine Gases Caused by Auxiliary Fans as Used in Coal Mines, by H. P. Greenwald and H. C. Howarth. 1928. Am. Inst. Min. and Met. Eng., Tech. Pub. No. 502. 1928. 20 pp.
Tunnel Ventilation Tests for Holland Vehicular Tunnel, New York to New Jersey. Rept. New York State Bridge and Tunnel Commission, 1921, 1922, and 1923, by A. C. Fieldner and others. Contains test data on production and diffusion of automobile and truck exhaust gases by air currents, and gives results of physiological tests of the effect of carbon monoxide.

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